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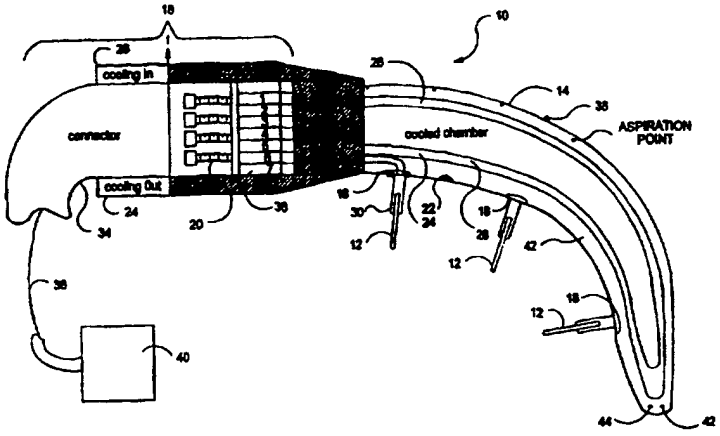

(57) Abstract

A method for reducing a volume of a tongue in an oral cavity provides an ablation apparatus. The ablation apparatus including a source of electromagnetic energy and one or more electromagnetic energy delivery electrodes coupled to the electromagnetic energy source. A distal end of the ablation apparatus is introduced into the oral cavity. The distal end of the ablation apparatus is positioned outside of an oral cavity gag response zone. At least one electrode is introduced into the interior of the tongue when the distal end of the ablation apparatus is positioned outside of the oral cavity gag response zone. A sufficient amount of electromagnetic energy is delivered from the electrode into the interior of the tongue to debulk a section of the tongue without damaging the hypoglossal nerve. The electrode is then removed from the interior of the tongue.

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APPARATUS AND METHOD FOR TREATING AIRWAY INSUFFICIENCY IN THE LARINGEAL/ORAL CAVITY REGION BY ELECTROMAGNETIC ENERGY.

Cross-Reference to Related Applications

This application is a continuation-in-part application of Docket Number SOMN 1009CIP2, entitled "METHOD FOR TREATMENT OF AIRWAY OBSTRUCTIONS", filed May 3, 1996, which is a continuation-in-part application of U.S. Patent Application No. 08/606,195, filed February 23, 1996, entitled "Method for Treatment of Airway Obstructions", which cross-references U.S. Patent Application No. 08/516,781 filed August 18, 1995, entitled "Ablation Apparatus and System for Removal of Soft Palate Tissue", having named inventors Stuart D. Edwards, Edward J. Gough and David L. Douglass, which is a continuation-in-part of U.S. Application No. 08/239,658, filed May 9, 1994 entitled "Method for Reducing Snoring by RF Ablation of the Uvula", and is related to Attorney Docket No. SOMN 1009CIP3, entitled "Method and Apparatus for Treatment of Air Way Obstructions" filed concurrent with this application, all incorporated by reference herein.

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a method for maintaining upper airway patency in human patients, and more particularly to a method which utilizes electromagnetic energy to debulk selected sections of the tongue, lingual tonsils and/or adenoids outside of an oral cavity gag response area without damaging the hypoglossal nerve.

Description of Related Art

Sleep-apnea syndrome is a medical condition characterized by daytime hypersomnomulence, morning arm aches, intellectual deterioration, cardiac arrhythmias, snoring and thrashing during sleep. It is caused by frequent

episodes of apnea during the patient's sleep. The syndrome is classically subdivided into two types. One type, termed "central sleep apnea syndrome", is characterized by repeated loss of respiratory effort. The second type, termed obstructive sleep apnea syndrome, is characterized by repeated apneic episodes during sleep resulting from obstruction of the patient's upper airway or that portion of the patient's respiratory tract which is cephalad to, and does not include, the larynx.

Treatment thus far includes various medical, surgical and physical measures. Medical measures include the use of medications such as protriptyline, medroxyprogesterone, acetazolamide, theophylline, nicotine and other medications in addition to avoidance of central nervous system depressants such as sedatives or alcohol. The medical measures above are sometimes helpful but are rarely completely effective. Further, the medications frequently have undesirable side effects.

Surgical interventions have included uvulopalatopharyngoplasty, tonsillectomy, surgery to correct severe retrognathia and tracheostomy. In one procedure the jaw is dislodged and pulled forward, in order to gain access to the base of the tongue. These procedures may be effective but the risk of surgery in these patients can be prohibitive and the procedures are often unacceptable to the patients.

Physical measures have included weight loss, nasopharyngeal airways, nasal CPAP and various tongue retaining devices used nocturnally. These measures may be partially effective but are cumbersome, uncomfortable and patients often will not continue to use these for prolonged periods of time. Weight loss may be effective but is rarely achieved by these patients.

In patients with central sleep apnea syndrome, phrenic nerve or diaphragmatic pacing has been used. Phrenic nerve or diaphragmatic pacing includes the use of electrical stimulation to regulate and control the patient's diaphragm which is innervated bilaterally by the phrenic nerves to assist or support ventilation. This pacing is disclosed in *Direct Diaphragm Stimulation*

by J. Mugica et al. PACE vol. 10 Jan-Feb. 1987, Part II, *Preliminary Test of a Muscular Diaphragm Pacing System on Human Patients* by J. Mugica et al. from Neurostimulation: An Overview 1985 pp. 263-279 and *Electrical Activation of Respiration* by Nochomovitez IEEE Eng. in Medicine and Biology; June, 1993.

However, it was found that many of these patients also have some degree of obstructive sleep apnea which worsens when the inspiratory force is augmented by the pacer. The ventilation induced by the activation of the diaphragm also collapses the upper airway upon inspiration and draws the patient's tongue inferiorly down the throat choking the patient. These patients then require tracheostomies for adequate treatment.

A physiological laryngeal pacemaker as described in *Physiological Laryngeal Pacemaker* by F. Kaneko et al. from Trans Am Soc Artif Intern Organs 1985 senses volume displaced by the lungs and stimulates the appropriate nerve to open the patient's glottis to treat dyspnea. This apparatus is not effective for treatment of sleep apnea. The apparatus produces a signal proportional in the displaced air volume of the lungs and thereby the signal produced is too late to be used as an indicator for the treatment of sleep apnea. There is often no displaced air volume in sleep apnea due to obstruction.

One measure that is effective in obstructive sleep apnea is tracheostomy. However, this surgical intervention carries considerable morbidity and is aesthetically unacceptable to many patients. Other surgical procedures include pulling the tongue as forward as possible and surgically cutting and removing sections of the tongue and other structures which can close off the upper airway passage.

There is a need for a method to treat airway obstruction disorders. There is a further need for a method to reduce the volume of the tongue, lingual tonsils or adenoids by ablating selected interior sections of the tongue, lingual tonsils or adenoids with an ablation apparatus distal end that is positioned in the oral cavity outside of an oral cavity gag response zone. Yet there is a further need for

determining the oral cavity gag response zone, and then deliver electromagnetic energy to the tongue, lingual tonsils or adenoid outside of the oral cavity gag response zone.

SUMMARY OF THE INVENTION

Accordingly, an object of the invention is to provide a method to treat airway obstructions.

Another object of the invention is to provide a method for ablating an interior of a body structure in the oral cavity outside of an oral cavity gag response zone.

Still another object of the invention is to provide a method for ablating an interior of a tongue, lingual tonsils or adenoids with a distal end of an ablation apparatus that is positioned outside of the oral cavity gag response zone.

Yet another object of the invention is to determine the location of a patient's oral cavity gag response zone.

These and other objects of the invention are achieved in a method for reducing a volume of a tongue in an oral cavity. An ablation apparatus is provided. The ablation apparatus includes a source of electromagnetic energy and one or more electromagnetic energy delivery electrodes coupled to the electromagnetic energy source. A distal end of the ablation apparatus is introduced into the oral cavity. The distal end of the ablation apparatus is positioned outside of an oral cavity gag response zone. At least one electrode is introduced into an interior of the tongue when the distal end of the ablation apparatus is positioned outside of the oral cavity gag response zone. A sufficient amount of electromagnetic energy is delivered from the electrode into the interior of the tongue to debulk a section of the tongue without damaging the hypoglossal nerve. The electrode is then removed from the interior of the tongue.

The method of the present invention is also used to treat airway obstructions, reduce the volume of the lingual tonsils or adenoids, and determine the oral cavity gag response zone.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1(a) is a cross-sectional view of an ablation apparatus used with the present invention.

Figure 1(b) is a perspective of the ablation apparatus of the present invention illustrating a catheter tissue interface surface.

Figure 2 is cross-sectional view illustrating the catheter and connector of the ablation apparatus shown in Figure 1(a).

Figure 3 is a perspective view of the connector illustrated in Figure 1(a).

Figure 4 is a perspective view of a needle electrode associated with the ablation apparatus illustrated in Figure 1(a).

Figure 5 is a perspective view of a flexible needle electrode utilized with the methods of the present invention.

Figure 6 illustrates the creation of ablation zones with the ablation apparatus shown in Figure 1(a).

Figure 7 is a cross-sectional view of the tongue with the mouth closed.

Figure 8 is a cross-sectional view of the tongue with the mouth open.

Figure 9 is a perspective view of the tongue.

Figure 10 is a perspective view of the dorsum of the tongue.

Figure 11 is a cross-sectional view of the tongue.

Figure 12 is a cross-sectional view of the tongue illustrating the location of the hypoglossal nerves and the creation of an ablation zone.

Figure 13 is a cross-sectional view of the tongue illustrating a plurality of ablation zones.

Figure 14 is a perspective view of the ventral surface of the tongue.

Figure 15 is a cross-sectional view of the tongue.

Figure 16 is a block diagram of a feedback control system useful with the methods of the present invention.

Figure 17 is a block diagram illustrating an analog amplifier, analog multiplexer and microprocessor used with the feedback control system of Figure 16.

Figure 18 is a block diagram of a temperature/impedance feedback system that can be used to control cooling medium flow rate through the catheter of Figure 1.

DETAILED DESCRIPTION

Referring to Figures 1(a), 1(b) and 2, an ablation apparatus 10 for debulking the tongue, lingual tonsils, and/or adenoids is illustrated. Ablation apparatus 10 can be positioned so that one or more electrodes 12 are introduced into an interior of the tongue through a surface of the tongue. Ablation apparatus 10 may include atraumatic intubation with or without visualization, provide for the delivery of oxygen or anesthetics, and can be capable of suctioning blood or other secretions. It will be appreciated that ablation apparatus 10 is used to treat a variety of different obstructions in the body where passage of gas is restricted. One embodiment is the treatment of sleep apnea using electrodes 12 to ablate selected portions of the tongue, lingual tonsils and/or adenoids by the use of RF, microwave, and the like. In this regard, ablation apparatus 10 can be used to ablate targeted masses including but not limited to the tongue, tonsils, turbinates, soft palate tissues, hard tissue and mucosal tissue. In one embodiment, ablation apparatus 10 is used to ablate an interior region of the tongue, causing it to become debulked in order to increase the cross-sectional area of the airway passage.

Prior to debulking the tongue, a presurgical evaluation may be performed including a physical examination, fiber optic pharyngoscopy, cephalometric analysis and polygraphic monitoring. The physical examination emphasizes the evaluation of the head and neck. It also includes a close examination of the nasal

cavity to identify obstructing deformities of the septum and turbinate; oropharyngeal obstruction from a long, redundant soft palate or hypertrophic tonsils; and hypopharyngeal obstruction from a prominent base of the tongue.

Ablation apparatus 10 includes a catheter 14, a handle 16, one or more electrodes 12 extending from different ports 18 formed along a longitudinal surface of catheter 14, or from a distal end of electrode 12. An electrode advancement and retraction device 20 is provided. Cabling is coupled to electrodes 12.

A distal end of catheter 14 is introduced into a patient's oral cavity. The distal end of catheter 14 is introduced, (i) a sufficient distance into the patient's oral cavity to provoke a gag response, or (ii) at a location that is outside of the oral cavity gag response zone. In any event, electrodes 12 are introduced into a body structure when the distal end of catheter 14 is outside of the oral cavity gag response zone.

In one embodiment, the distal end of catheter 14 is introduced into the patient's oral cavity a sufficient distance to initiate a gag response. The distal end of catheter 14 is then positioned outside of the oral cavity gag response zone and the delivery of electromagnetic energy by electrodes 12 proceeds. Catheter 14 can be provided with scale markings on an exterior surface. Once the oral cavity gag response zone is determine, and the distal end of catheter 14 is positioned outside of the oral cavity gag response zone, that distance is noted by the scale markings.

A volume of a tongue is reduced by introducing a distal end of catheter 14 outside of the oral cavity gag response zone and then the ablation of the tongue proceeds. Similarly, a volume of the lingual tonsils, and/or the adenoids is also reduced when the distal end of catheter 14 is positioned outside of the oral cavity gag response zone.

In other embodiments, the oral cavity gag response zone is not determined but the distal end of catheter 14 is positioned in the oral cavity in a position where it is not in the oral cavity gag response zone.

Electrodes 12 are at least partially positioned in an interior of catheter 14. Each electrode 12 is advanced and retracted through a port 18 formed in an exterior surface of catheter 14. Electrode advancement and retraction device advances electrodes 12 out of catheter 14, into an interior of a body structure and retracted back into catheter 14. Although the body structure can be any number of different structures, the body structure will hereafter be referred to as the tongue. Electrodes 12 pierce an exterior surface of the tongue and are directed to an interior region of the tongue. Sufficient electromagnetic energy is delivered by electrodes 12 to the interior of the tongue to cause the tongue to become sufficiently ablated and debulked. Electrodes 12 can be hollow to receive a variety of different infusion mediums, including but not limited to saline. Electrodes 12 may be limited in the distance that they can be advanced into the tongue. This is achieved with an insulation sleeve, a structure located on electrodes 12 which limits their advancement, or a structure coupled to catheter which limits the advancement of electrodes 12, such as a stop and the like.

Electrodes 12 can include a central lumen for receiving a variety of fluids that can be introduced into the interior of the tongue, as well as a plurality of fluid delivery ports. One suitable fluid is an electrolytic solution. Instead of direct contact with tissue and electrode 12 for the delivery of thermal energy, a cooled electrolytic solution can be used to deliver the thermal energy to the tissue. The electrolytic solution may be cooled in the range of about 30 to 55 degrees C.

Catheter 14 includes a catheter tissue interface surface 22, a cooling medium inlet conduit 24 and a cooling medium exit conduit 26 extending through an interior of catheter 14. Ports 18 are formed in the exterior of catheter 14, and are preferably formed on catheter tissue interface surface 22. Ports 18 are isolated from a cooling medium flowing in inlet and outlet conduits 24 and 26. Cooling medium inlet and exit conduits 24 and 26 are configured to provide a cooled section of catheter tissue interface surface 22 of at least 1 to 2 cm^2. More preferably, the cooled section of catheter tissue interface surface 22

is at least equal to the cross-sectional diameter of the underlying zone of ablation.

The size of the cooled section of catheter tissue interface surface 22 varies for each patient. The size is sufficient enough to minimize swelling of the tongue following the delivery of electromagnetic energy. The reduction of swelling can be 50% or greater, 75% or greater , and 90% and greater. The amount of cooling provided is sufficient to enable the patient to return home shortly after the debulking procedure is performed, and not run the risk of choking on the tongue. It has been found that by providing a sufficient level of cooling over a relatively large area, the amount of ablation in an interior region of the tongue is enhanced. By providing a sufficiently large enough cooled section of catheter tissue interface surface 22, an adenomas response is minimized.

An electromagnetic energy delivery surface 30 of electrode 12 can be adjusted by inclusion of an adjustable or non-adjustable insulation sleeve 32 (Figures 3, 4, and 5). Insulation sleeve 32 can be advanced and retracted along the exterior surface of electrode 12 in order to increase or decrease the length of the electromagnetic energy delivery surface 30. Insulation sleeve 32 can be made of a variety of materials including but not limited to nylon, polyimides, other thermoplastics and the like. The size of electromagnetic energy delivery surface 30 can be varied by other methods including but not limited to creating a segmented electrode with a plurality of electrodes that are capable of being multiplexed and individually activated, and the like.

Handle 16 is preferably made of an insulating material. Electrodes 12 are made of a conductive material such as stainless steel. Additionally, electrodes 12 can be made of a shaped memory metal, such as nickel titanium, commercially available from Raychem Corporation, Menlo Park, California. In one embodiment, only a distal end of electrode 12 is made of the shaped memory metal in order to effect a desired deflection. When introduced into the oral cavity, catheter 14 can be advanced until a patient's gag response is initiated.

Catheter 14 is then retracted back to prevent patient's gagging. The distal end of electrode 12 can be semi-curved. The distal end can have a geometry to conform to an exterior of the tongue.

Catheter 14 can be malleable in order to conform to the surface of the tongue when a selected ablation target site is selected. An encapsulated soft metal, such as copper, or an annealed metal/plastic material can be used to form malleable catheter 14. All or a portion of catheter 14 may be malleable or made of a shaped memory metal.

For many applications it is desirable for a distal end 14' of catheter 14 to be deflectable. This can be achieved mechanically or with the use of memory metals. A steering wire, or other mechanical structure, can be attached to either the exterior or interior of distal end 14'. In one embodiment, a deflection knob located on handle 16 is activated by the physician causing a steering wire to tighten. This imparts a retraction of distal end 14', resulting in its deflection. It will be appreciated that other mechanical devices can be used in place of the steering wire. The deflection may be desirable for tissue sites with difficult access.

Handle 6 can comprise a connector 34 coupled to retraction and advancement device 20. Connector 34 provides a coupling of electrodes 12 to power, feedback control, temperature and/or imaging systems. An RF/temperature control block 36 can be included.

In one embodiment, the physician moves retraction and advancement device 20 in a direction toward a distal end of connector 34. Electrodes 12 can be spring loaded. When retraction and advancement device 20 is moved back, springs cause selected electrodes 12 to advance out of catheter 14.

One or more cables 38 couple electrodes 12 to an electromagnetic energy source 40. A variety of energy sources 40 can be used with the present invention to transfer electromagnetic energy to the interior of a body structure, including but not limited to RF, microwave, ultrasound, coherent light and thermal transfer. Preferably, energy source 40 is a RF generator. When a RF

energy source is used, the physician can activate RF energy source 40 by the use of a foot switch (not shown) coupled to RF energy source 40.

One or more sensors 42 may be positioned on an interior or exterior surface of electrode 12, insulation sleeve 32, or be independently inserted into the interior of the body structure. Sensors 42 permit accurate measurement of temperature at a tissue site in order to determine, (i) the extent of ablation, (ii) the amount of ablation, (iii) whether or not further ablation is needed, and (iv) the boundary or periphery of the ablated geometry. Further, sensors 42 prevent non-targeted tissue from being destroyed or ablated.

Sensors 42 are of conventional design, including but not limited to thermistors, thermocouples, resistive wires, and the like. Suitable sensors 42 include a T type thermocouple with copper constantene, J type, E type, K type, fiber optics, resistive wires, thermocouple IR detectors, and the like. It will be appreciated that sensors 42 need not be thermal sensors.

Sensors 42 measure temperature and/or impedance to permit ablation monitoring. This reduces damage to tissue surrounding the targeted ablation mass. By monitoring the temperature at various points within the interior of the body structure the periphery of ablation can be ascertained and it is possible to determine when the ablation is completed. If at any time sensor 42 determines that a desired ablation temperature is exceeded, then an appropriate feedback signal is received at energy source 40 and the amount of energy delivered is regulated.

Ablation apparatus 10 can include visualization capability including but not limited to a viewing scope, an expanded eyepiece, fiber optics, video imaging, and the like.

Additionally, ultrasound imaging can be used to position the electrodes 12 and/or determine the amount of ablation. One or more ultrasound transducers 44 can be positioned in or on electrode 12, catheter 14, or on a separate device. An imaging probe may also be used internally or externally to the selected tissue site. A suitable imaging probe is Model 21362, manufactured

and sold by Hewlett Packard Company. Each ultrasound transducer 44 is coupled to an ultrasound source (not shown).

With reference now to Figure 6 catheter 14 is shown as being introduced into the oral cavity and multiple RF electrodes 12 are advanced into the interior of the tongue creating different ablation zones 46. Ablation apparatus 10 can be operated in either bipolar or monopolar modes. In Figure 6, electrodes 12 are operated in the bipolar mode, creating sufficient ablation zones 46 to debulk the tongue without affecting the hypoglossal nerves and creating a larger airway passage. With this debulking, the back of the tongue moves in a forward direction away from the air passageway. The result is an increase in the cross-sectional diameter of the air passageway.

Ablation apparatus 10 can also be operated in the monopolar mode. A groundpad can be positioned in a convenient place such as under the chin. A single electrode 12 is positioned in the tongue to create a first ablation zone 46. Electrode 12 can then be retracted from the interior of the tongue, catheter 14 moved, and electrode 12 is then advanced from catheter 14 into another interior section of the tongue. A second ablation zone 46 is created. This procedure can be completed any number of times to form different ablation regions in the interior of the tongue. More than one electrode 12 can be introduced into the tongue and operated in the bipolar mode. Electrodes 12 are then repositioned in the interior of the tongue any number of times to create a plurality of connecting or non-connecting ablation zones 46.

Referring now to Figures 7 through 15, various anatomical views of the tongue and other structures are illustrated. The different anatomical structures are as follows: the genioglossus muscle, or body of the tongue is denoted as 48; the geniohyoid muscle is 50; the mylohyoid muscle is 52; the hyoid bone is 54; the tip of the tongue is 56; the ventral surface of the tongue is denoted as 58; the dorsum of the tongue is denoted as 60; the inferior dorsal of the tongue is denoted as 62; the reflex of the vallecula is 64; the lingual follicles are denoted as 66; the uvula is 68; the adenoid area is 70; the lateral border of the tongue is 72;

the circumvallate papilla is 74, the palatine tonsil is 76; the pharynx is 78; the redundant pharyngeal tissue is 80; the foramen cecum is 82; the hypoglossal nerve is 84, and the lingual frenum of the tongue is 86.

Dorsum 60 is divided into an anterior 2/3 and inferior dorsal 62. The delineation is determined by circumvallate papilla 74 and foramen cecum 82. Inferior dorsal 62 is the dorsal surface inferior to circumvallate papilla 74 and superior reflex of the vallecula 64. Reflex of the vallecula 64 is the deepest portion of the surface of the tongue contiguous with the epiglottis. Lingual follicles 66 comprise the lingual tonsil.

Catheter 14 can be introduced through the nose or through the oral cavity. Electrodes 12 can be inserted into an interior of the tongue through dorsum surface 60, inferior dorsal surface 62, ventral surface 58, tip 56 or geniohyoid muscle 50. Additionally, electrodes may be introduced into an interior of lingual follicles 66 and into adenoid area 70. Once electrodes 12 are positioned, insulation sleeve 32 may be adjusted to provided a desired electromagnetic energy delivery surface 30 for each electrode 12.

Ablation zones 46 are created without damaging hypoglossal nerves 84. This creates a larger air way passage and provides a treatment for sleep apnea.

In all instances, the positioning of electrodes 12, as well as the creation of ablation zones 46 is such that hypoglossal nerves 84 are not ablated or damaged. The ability to swallow and speak is not impaired.

Referring now to Figures 16 and 17 an open or closed loop feedback system couples sensors 42 to energy source 40. The temperature of the tissue, or of electrode 12 is monitored, and the output power of energy source 40 adjusted accordingly. The physician can, if desired, override the closed or open loop system. A microprocessor can be included and incorporated in the closed or open loop system to switch power on and off, as well as modulate the power. The closed loop system utilizes a microprocessor 88 to serve as a controller, watch the temperature, adjust the RF power, look at the result, refeed the result, and then modulate the power.

With the use of sensors 42 and the feedback control system a tissue adjacent to RF electrodes 12 can be maintained at a desired temperature for a selected period of time without impeding out. Each RF electrode 12 is connected to resources which generate an independent output for each RF electrode 12. An output maintains a selected energy at RF electrodes 12 for a selected length of time.

Current delivered through RF electrodes 12 is measured by current sensor 90. Voltage is measured by voltage sensor 92. Impedance and power are then calculated at power and impedance calculation device 94. These values can then be displayed at user interface and display 96. Signals representative of power and impedance values are received by a controller 98.

A control signal is generated by controller 98 that is proportional to the difference between an actual measured value, and a desired value. The control signal is used by power circuits 100 to adjust the power output in an appropriate amount in order to maintain the desired power delivered at respective RF electrodes 12.

In a similar manner, temperatures detected at sensors 42 provide feedback for maintaining a selected power. The actual temperatures are measured at temperature measurement device 102, and the temperatures are displayed at user interface and display 96. A control signal is generated by controller 98 that is proportional to the difference between an actual measured temperature, and a desired temperature. The control signal is used by power circuits 100 to adjust the power output in an appropriate amount in order to maintain the desired temperature delivered at the respective sensor. A multiplexer can be included to measure current, voltage and temperature, at the numerous sensors 42, and energy can be delivered to RF electrodes 12 in monopolar or bipolar fashion.

Controller 98 can be a digital or analog controller, or a computer with software. When controller 98 is a computer it can include a CPU coupled through a system bus. On this system can be a keyboard, a disk drive, or other

non-volatile memory systems, a display, and other peripherals, as are known in the art. Also coupled to the bus is a program memory and a data memory.

User interface and display 96 includes operator controls and a display. Controller 98 can be coupled to imaging systems, including but not limited to ultrasound, CT scanners, X-ray, MRI, mammographic X-ray and the like. Further, direct visualization and tactile imaging can be utilized.

The output of current sensor 90 and voltage sensor 92 is used by controller 98 to maintain a selected power level at RF electrodes 12. The amount of RF energy delivered controls the amount of power. A profile of power delivered can be incorporated in controller 98, and a preset amount of energy to be delivered can also be profiled.

Circuitry, software and feedback to controller 98 result in process control, and the maintenance of the selected power that is independent of changes in voltage or current, and are used to change, (i) the selected power, (ii) the duty cycle (on-off and wattage), (iii) bipolar or monopolar energy delivery, and (iv) infusion medium delivery, including flow rate and pressure. These process variables are controlled and varied, while maintaining the desired delivery of power independent of changes in voltage or current, based on temperatures monitored at sensors 42.

Current sensor 90 and voltage sensor 92 are connected to the input of an analog amplifier 104. Analog amplifier 104 can be a conventional differential amplifier circuit for use with sensors 42. The output of analog amplifier 104 is sequentially connected by an analog multiplexer 106 to the input of A/D converter 108. The output of analog amplifier 104 is a voltage which represents the respective sensed temperatures. Digitized amplifier output voltages are supplied by A/D converter 108 to microprocessor 88. Microprocessor 88 may be a type 68HCII available from Motorola. However, it will be appreciated that any suitable microprocessor or general purpose digital or analog computer can be used to calculate impedance or temperature.

Microprocessor 88 sequentially receives and stores digital representations of impedance and temperature. Each digital value received by microprocessor 88 corresponds to different temperatures and impedances.

Calculated power and impedance values can be indicated on user interface and display 96. Alternatively, or in addition to the numerical indication of power or impedance, calculated impedance and power values can be compared by microprocessor 88 with power and impedance limits. When the values exceed predetermined power or impedance values, a warning can be given on user interface and display 96, and additionally, the delivery of RF energy can be reduced, modified or interrupted. A control signal from microprocessor 88 can modify the power level supplied by energy source 40.

Figure 18 illustrates a block diagram of a temperature/impedance feedback system that can be used to control cooling medium flow rate through catheter 14. Electromagnetic energy is delivered to electrode 12 by energy source 44, and applied to tissue. A monitor 110 ascertains tissue impedance, based on the energy delivered to tissue, and compares the measured impedance value to a set value. If the measured impedance exceeds the set value a disabling signal 112 is transmitted to energy source 40, ceasing further delivery of energy to electrode 12. If measured impedance is within acceptable limits, energy continues to be applied to the tissue. During the application of energy to tissue sensor 42 measures the temperature of tissue and/or electrode 12. A comparator 114 receives a signal representative of the measured temperature and compares this value to a pre-set signal representative of the desired temperature. Comparator 114 sends a signal to a flow regulator 116 representing a need for a higher cooling medium flow rate, if the tissue temperature is too high, or to maintain the flow rate if the temperature has not exceeded the desired temperature.

The foregoing description of a preferred embodiment of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obviously,

many modifications and variations will be apparent to practitioners skilled in this art. It is intended that the scope of the invention be defined by the following claims and their equivalents.

What is claimed is:

CLAIMS

1. A method for reducing a volume of a tongue in an oral cavity, comprising:

providing an ablation apparatus including a source of electromagnetic energy and one or more electromagnetic energy delivery electrodes coupled to the electromagnetic energy source;

introducing a distal end of the ablation apparatus into the oral cavity;

positioning the distal end of the ablation apparatus outside of an oral cavity gag response zone;

advancing at least one electrode into an interior of the tongue;

delivering a sufficient amount of electromagnetic energy from the electrode into the interior of the tongue to debulk a section of the tongue without damaging the hypoglossal nerve; and

retracting the electrode from the interior of the tongue.

2. The method of claim 1, wherein the energy source is an RF source.

3. The method of claim 1, wherein the energy source is a microwave source.

4. The method of claim 1, wherein the electrode is advanced into an interior of the tongue through a ventral surface of the tongue.

5. The method of claim 1, wherein the electrode is advanced into an interior of the tongue through an inferior dorsal surface of the tongue.

6. The method of claim 1, wherein the electrode is advanced into an interior of the tongue through a dorsum surface of the tongue.

7. The method of claim 1, wherein the electrode is advanced into an interior of the tongue through a tip of the tongue.

8. The method of claim 1, wherein two or more electrodes are advanced into a different interior area of the tongue.

9. The method of claim 1, wherein two or more electrodes are introduced through a different surface site of the tongue.

10. The method of claim 1, wherein the ablation apparatus further comprises:

a catheter including a lumen, wherein the electrode is deployed from the catheter lumen into an interior of the tongue.

11. The method of claim 1, wherein the catheter further comprises:

a cooling element.

12. The method of claim 11, wherein the cooling element comprises a cooling channel in an interior of the catheter, the cooling channel receiving a cooling medium and circulating the cooling medium through the interior of the catheter.

13. The method of claim 12, further comprising:

cooling a surface of the tongue while an electrode ablates an interior section of the tongue.

14. The method of claim 10, wherein the catheter is introduced into the oral cavity and one or more electrodes are introduced into an interior of the tongue through one of an inferior dorsal surface of the tongue, a dorsum surface of the tongue, or a tip of the tongue.

15. The method of claim 10, wherein the catheter is introduced into the oral cavity and one or more electrodes are introduced into an interior of the tongue through a ventral surface of the tongue.

16. The method of claim 1, further comprising:

providing an imaging apparatus.

17. The method of claim 16, wherein the imaging apparatus is an ultrasound device.

18. The method of claim 16, further comprising:

imaging the tongue prior to debulking the tongue.

19. The method of claim 16, further comprising:

imaging the tongue after debulking the tongue.

20. A method for treating airway obstructions, comprising:

providing an ablation apparatus including a source of electromagnetic energy and one or more electromagnetic energy delivery electrodes coupled to the electromagnetic energy source;

introducing a distal end of the ablation apparatus into an oral cavity;

determining an oral cavity gag response zone;

positioning the distal end of the ablation apparatus outside of the oral cavity gag response zone;

advancing at least one electrode into an interior of a tongue when the distal end of the ablation apparatus is positioned outside of the oral cavity gag response zone;

delivering sufficient electromagnetic energy from the electrode into the interior of the tongue to debulk an interior section without damaging a hypoglossal nerve; and

retracting the electrode from the interior of the tongue.

21. The method of claim 20, wherein the electrode is advanced into an interior of the tongue through a ventral surface of the tongue.

22. The method of claim 20, wherein the electrode is advanced into an interior of the tongue through an inferior dorsal surface of the tongue.

23. The method of claim 20, wherein the electrode is advanced into an interior of the tongue through a dorsum surface of the tongue.

24. The method of claim 20, wherein the electrode is advanced into an interior of the tongue through a tip of the tongue.

25. The method of claim 20, wherein the ablation apparatus further comprises:

a catheter including a lumen, wherein the electrode is deployed from the catheter lumen into an interior of the tongue.

26. The method of claim 25, wherein the catheter is introduced into the oral cavity and one or more electrodes are introduced into an interior of the tongue through one of an inferior dorsal surface of the tongue, a dorsum surface of the tongue, or a tip of the tongue.

27. The method of claim 25, wherein the catheter is introduced into the oral cavity and one or more electrodes are introduced into an interior of the tongue through a ventral surface of the tongue.

28. The method of claim 20, wherein the energy source is an RF source.

29. The method of claim 20, wherein the tongue is debulked sufficiently to increase a cross-sectional area of the airway passage.

30. The method of claim 20, further comprising:

providing an imaging apparatus.

31. The method of claim 30, further comprising:

imaging the tongue prior to debulking.

32. The method of claim 30, further comprising:

imaging the tongue after debulking.

33. A method for treating airway obstructions, comprising:

providing an ablation apparatus including a source of electromagnetic energy and one or more electromagnetic energy delivery electrodes coupled to the electromagnetic energy source;

positioning a distal end of the ablation apparatus outside of an oral cavity gag response zone;

advancing at least one electrode into a lingual tonsil;

delivering sufficient electromagnetic energy from the electrode into an interior of the lingual tonsil and debulk the lingual tonsil when a distal end of the ablation apparatus is positioned outside of an oral cavity gag response zone; and

retracting the electrode from the lingual tonsil.

34. The method of claim 33, wherein the energy source is an RF source.

35. The method of claim 33, wherein one or more electrodes are advanced into a different section of the lingual tonsil.

36. The method of claim 33, further comprising:

providing an imaging apparatus.

37. The method of claim 36, wherein the imaging apparatus is an ultrasound device.

38. The method of claim 36, further comprising:

imaging the lingual tonsil prior to debulking.

39. The method of claim 36, further comprising:

imaging the lingual tonsil after debulking.

40. A method for treating airway obstructions, comprising:

providing an ablation apparatus including a catheter with a catheter tissue interface surface, an electrode at least partially positioned in an interior of the catheter and advanceable and retractable to and from the catheter into an interior of a body structure, and a means for cooling the catheter tissue interface surface;

positioning a distal end of the ablation apparatus outside of an oral cavity gag response zone;

advancing the electrode from the interior of the catheter through a body structure external surface into the interior of the body structure when a distal end of the ablation apparatus is positioned outside of an oral cavity gag response zone;

delivering sufficient energy from the electrode into the interior of the body structure to ablate a portion of the interior of the body structure;

cooling the catheter tissue interface surface sufficiently to reduce a swelling of the body structure external surface; and

retracting the electrode from the interior of the body structure.

41. The method of claim 40, wherein the body structure is the tongue.

42. The method of claim 41, wherein the external body surface is a dorsum surface of the tongue.

43. The method of claim 41, wherein the exterior body surface is a ventral surface of the tongue.

44. The method of claim 41, wherein the exterior surface is an inferior dorsal surface of the tongue.

45. The method of claim 41, wherein sufficient electromagnetic energy is delivered to an interior of the tongue to ablate at least a portion of the interior of tongue with a minimal ablation of a surface of the tongue.

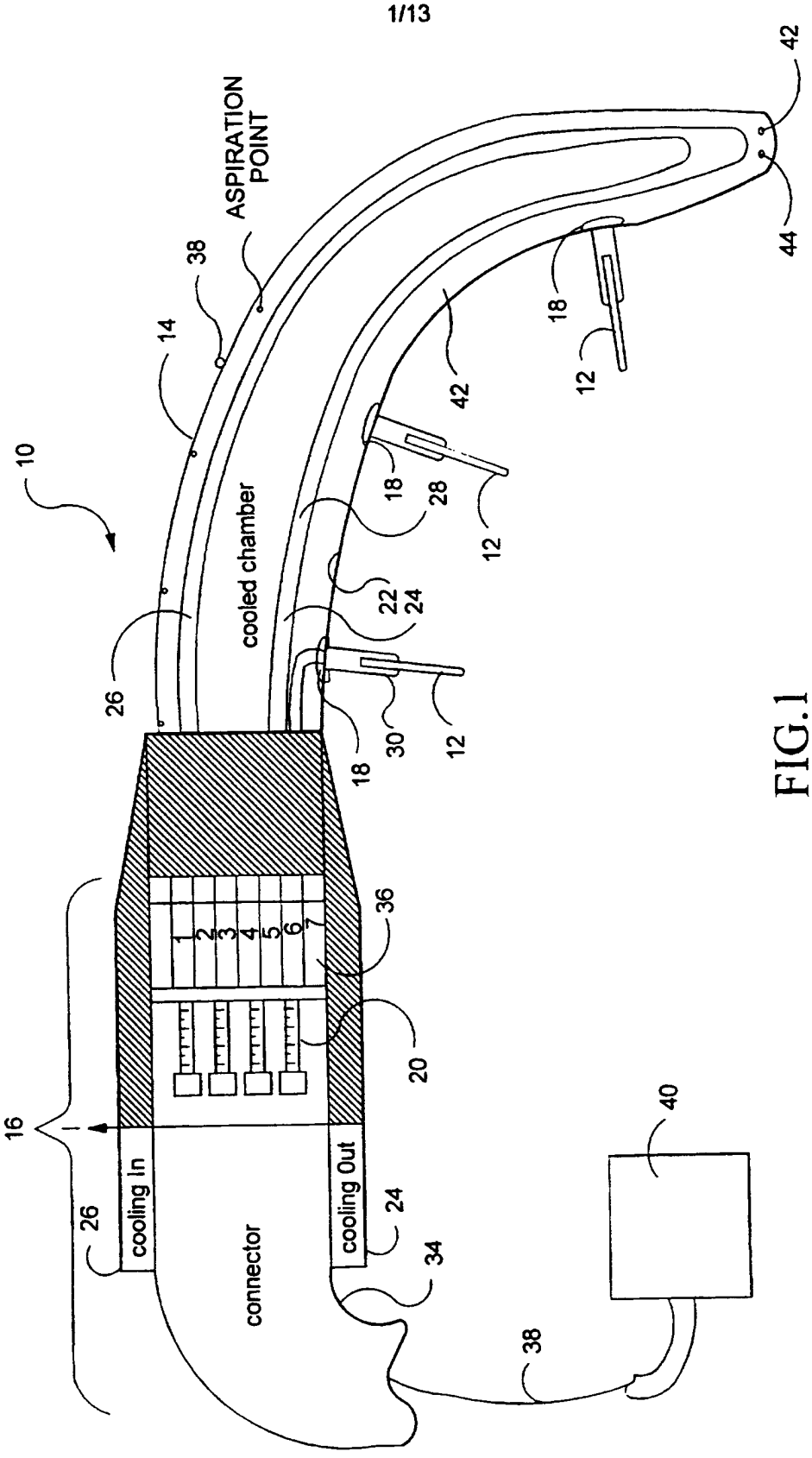
46. The method of claim 45, wherein a taste buds on the surface of the tongue are not ablated.

47. The method of claim 40, wherein the catheter tissue interface surface is cooled to a temperature of 10 to 30 degrees C.

48. The method of claim 40, wherein at least 1 cm2 of the catheter tissue interface surface is cooled.

49. The method of claim 40, wherein the ablation apparatus includes two or more electrodes, each advanced and retracted from a separate port formed in the catheter tissue interface surface.

50. The method of claim 41, wherein the interior of the tongue is sufficiently ablated to increase a cross-sectional area of an airway passage.


ASPIRATION POINT
cooled chamber
cooling In
cooling Out
connector
10
12
14
16
18
20
22
24
26
28
30
34
36
38
40
42
44
1
2
3
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6
7

FIG.1

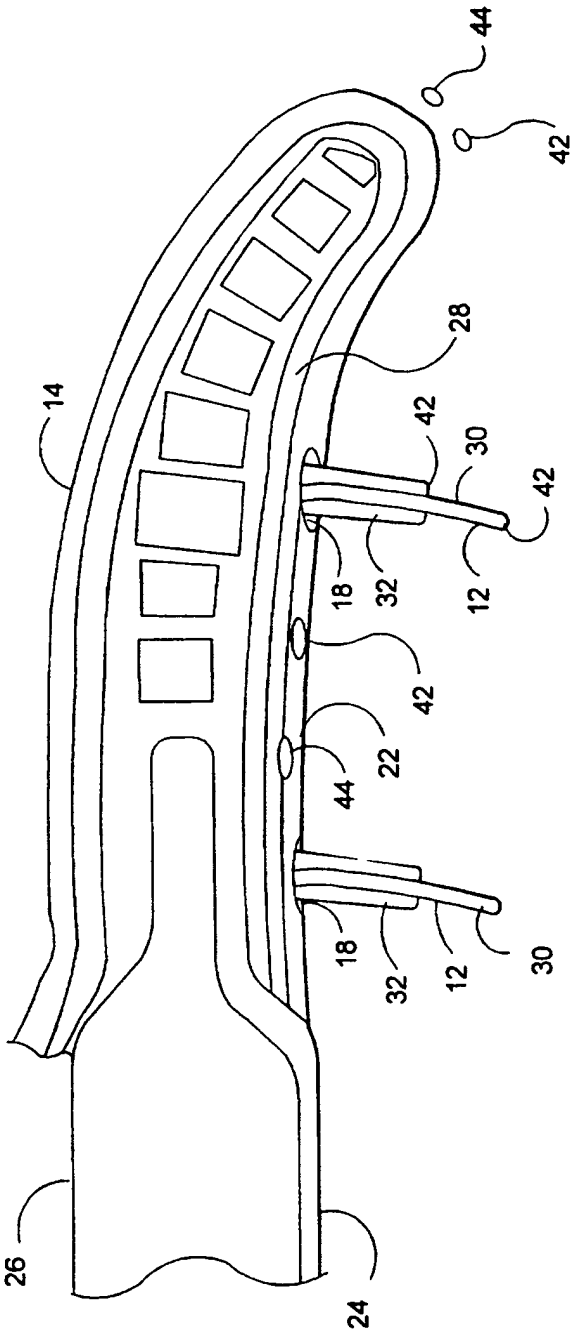
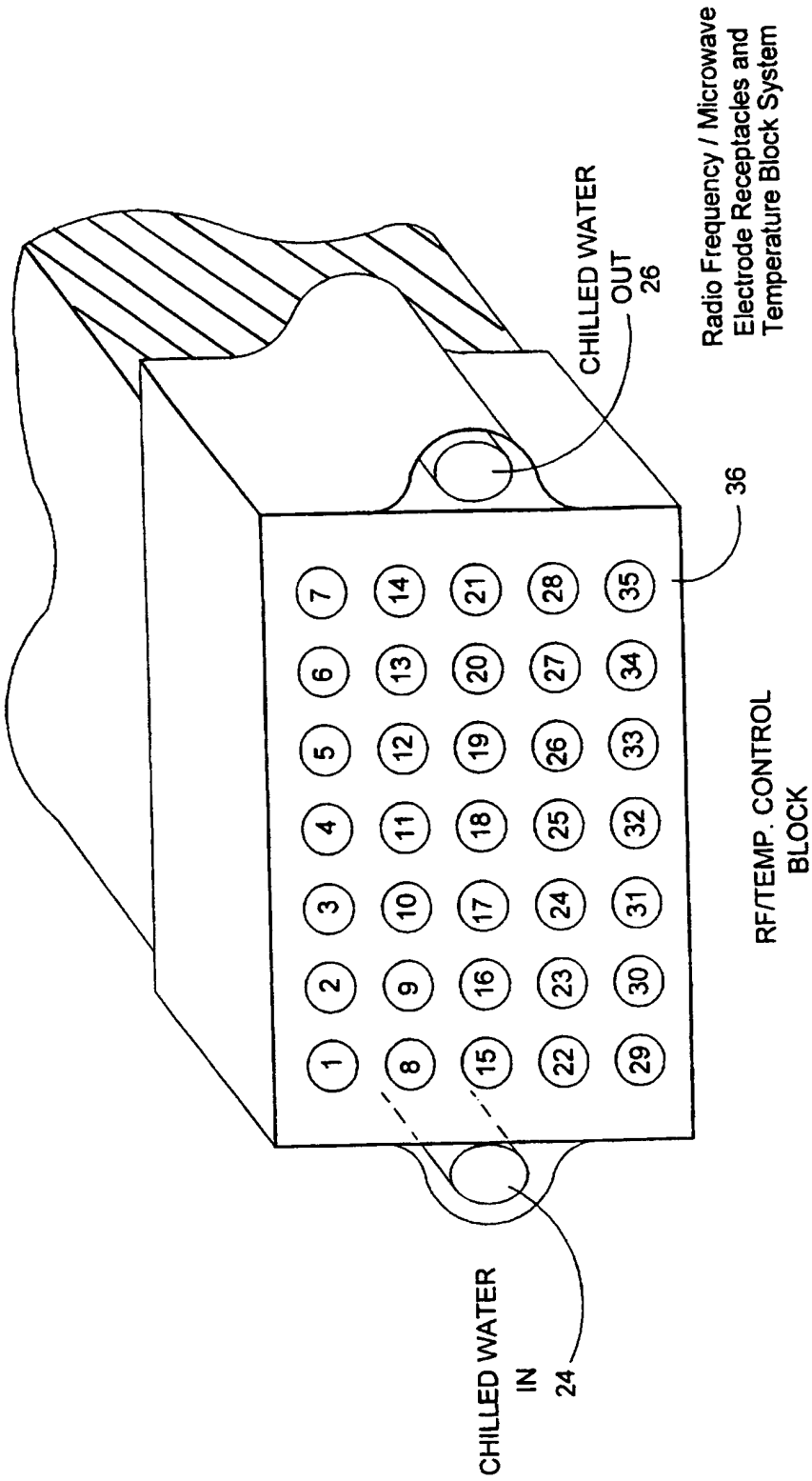


FIG.2


Radio Frequency / Microwave
Electrode Receptacles and
Temperature Block System
CHILLED WATER
OUT
26
36
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
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35
RF/TEMP. CONTROL
BLOCK
CHILLED WATER
IN
24

FIG.3

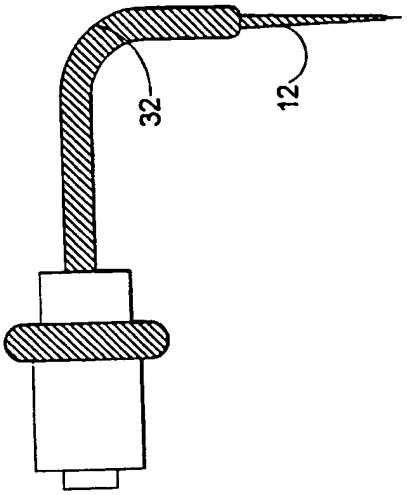

FIG.5

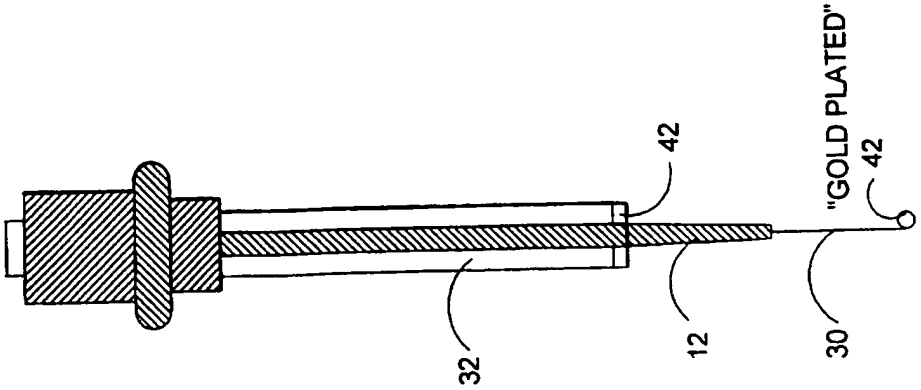

FIG.4

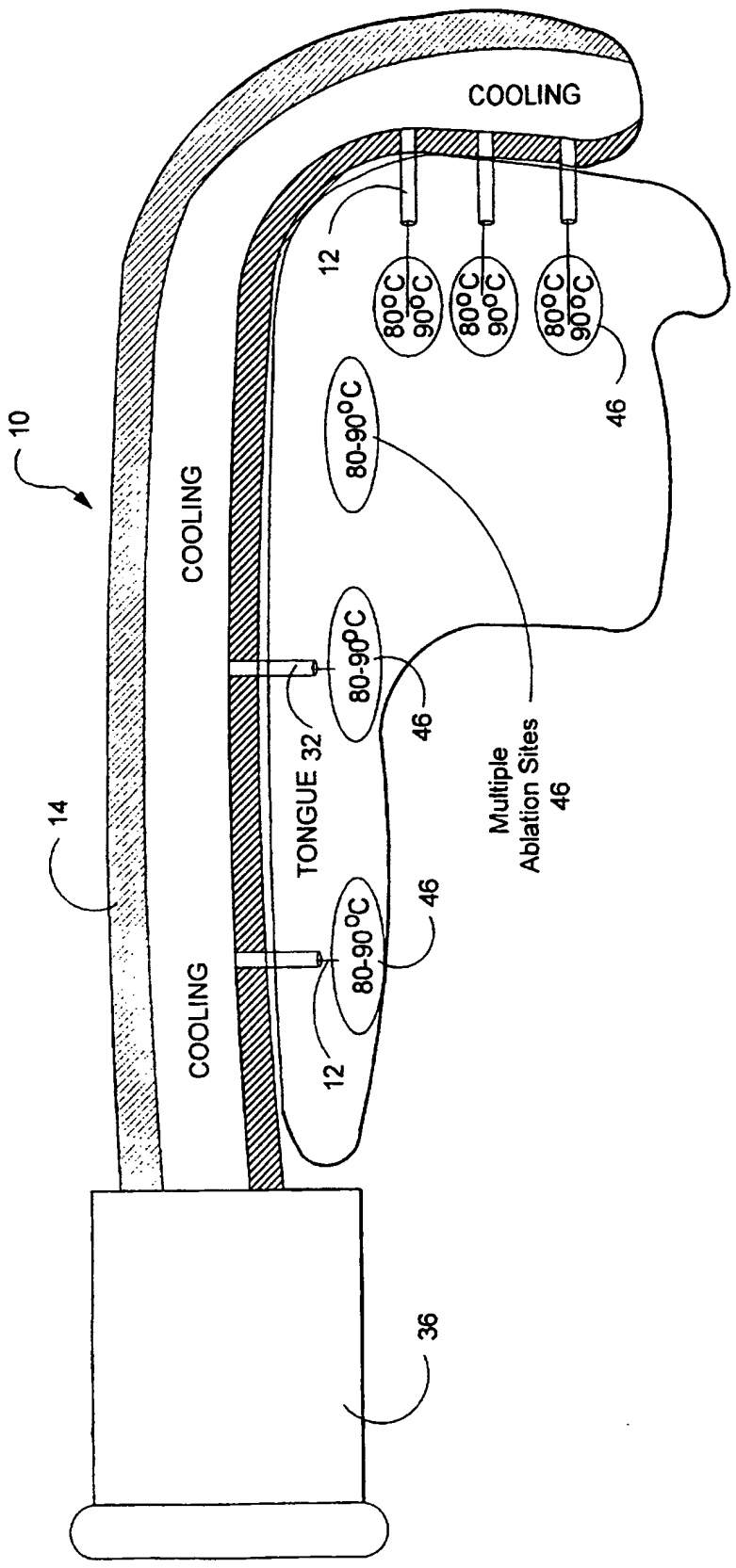
COOLING
12
80°C
90°C
80°C
90°C
80°C
90°C
46
10
80-90°C
COOLING
80-90°C
46
TONGUE 32
Multiple
Ablation Sites
46
14
80-90°C
46
COOLING
12
36

FIG.6

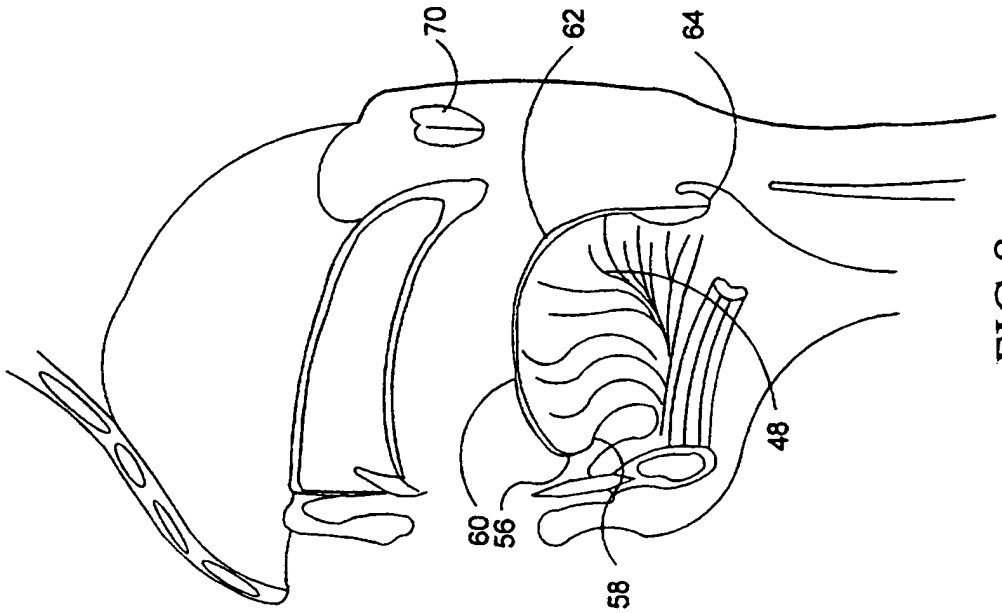

FIG.8

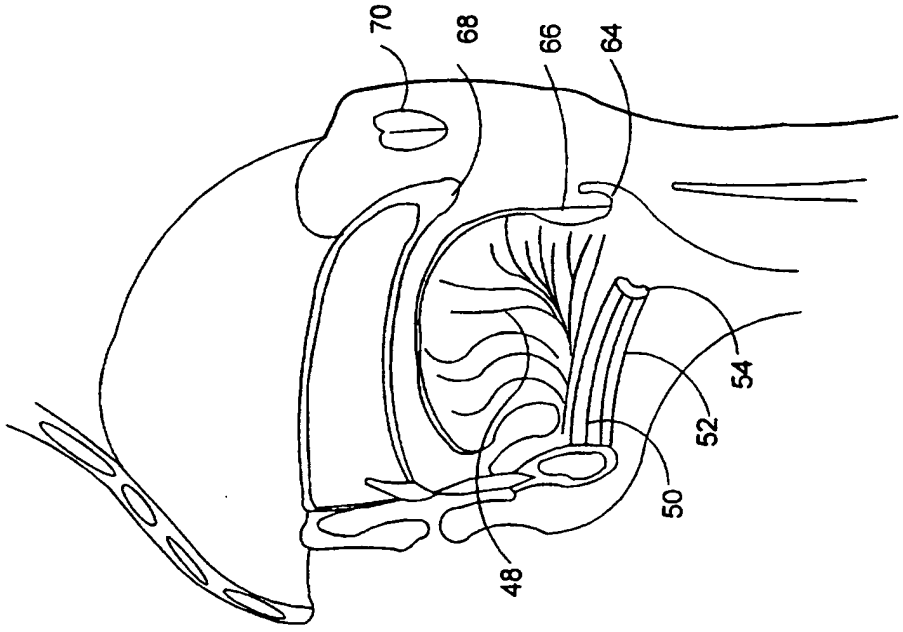

FIG.7

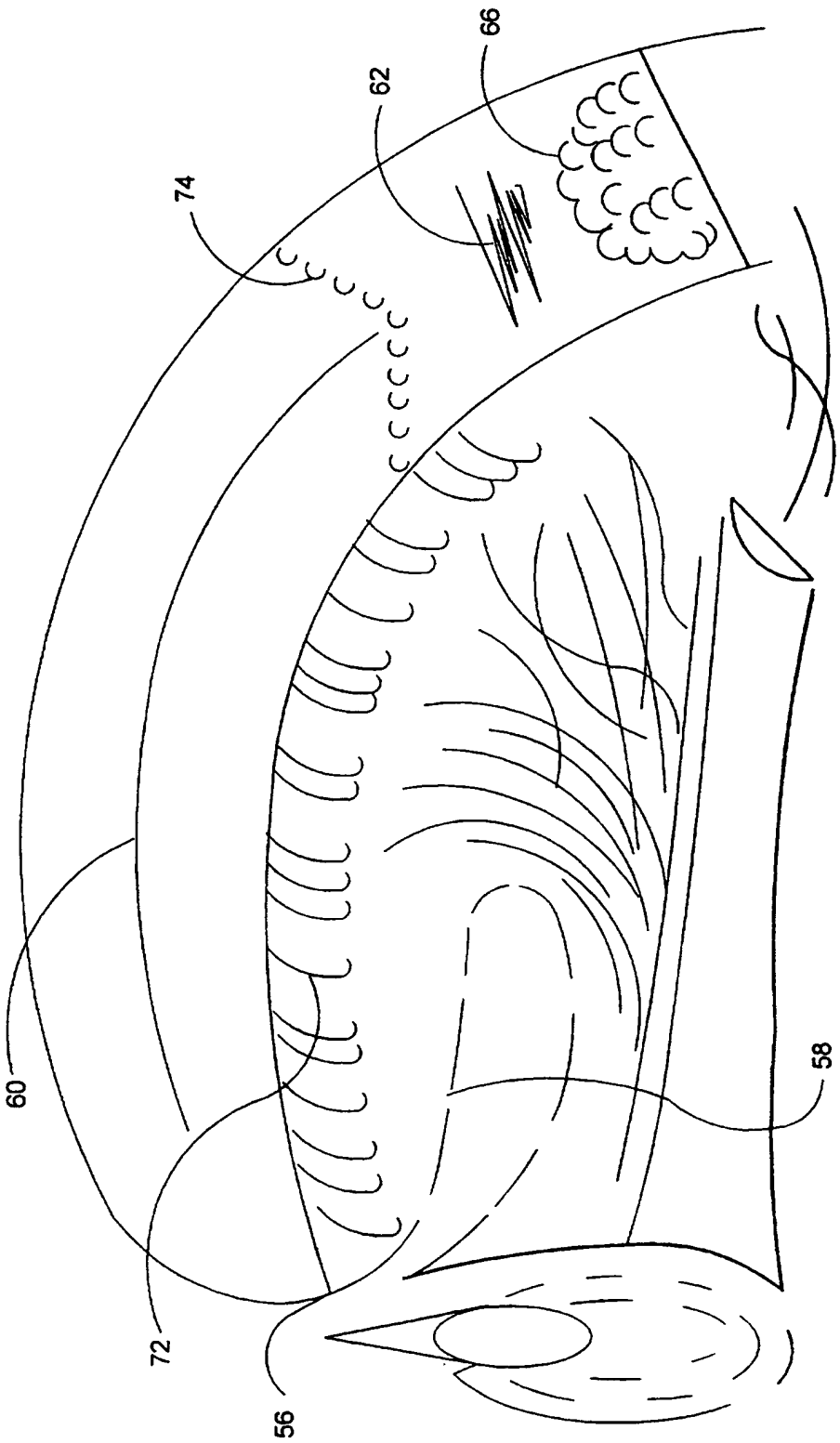

FIG.9

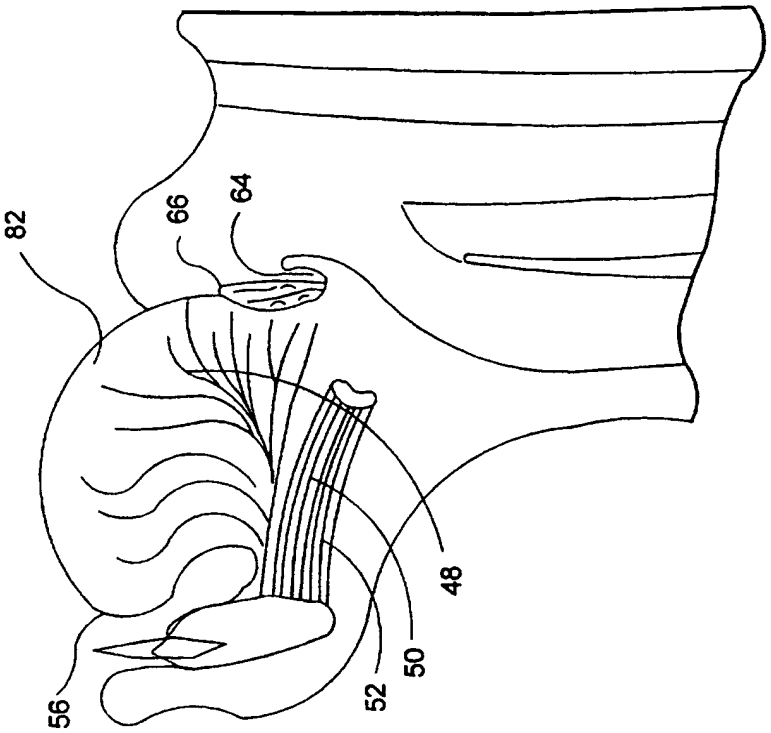

FIG.11

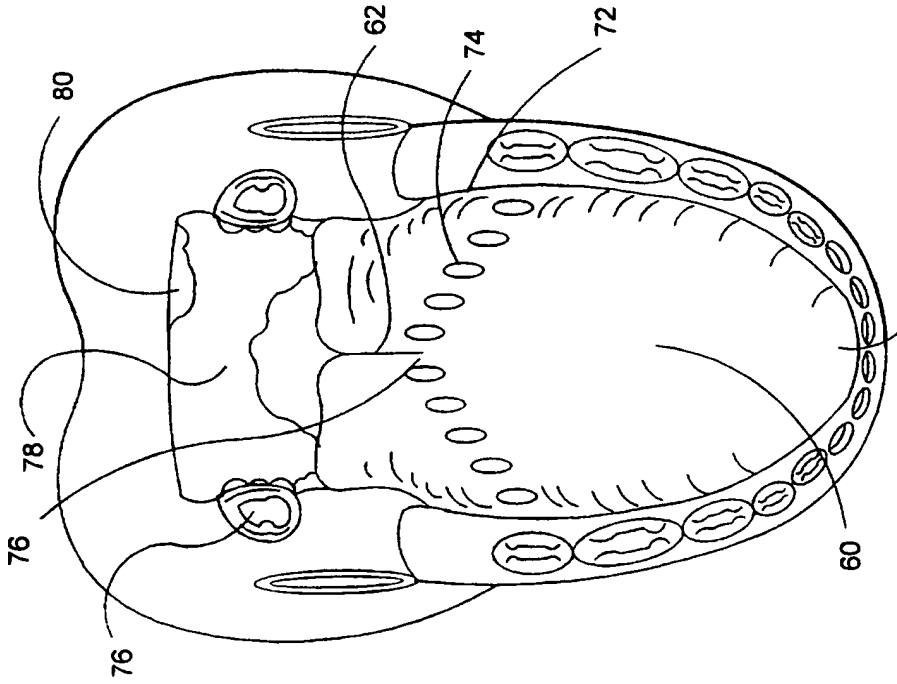

FIG.10

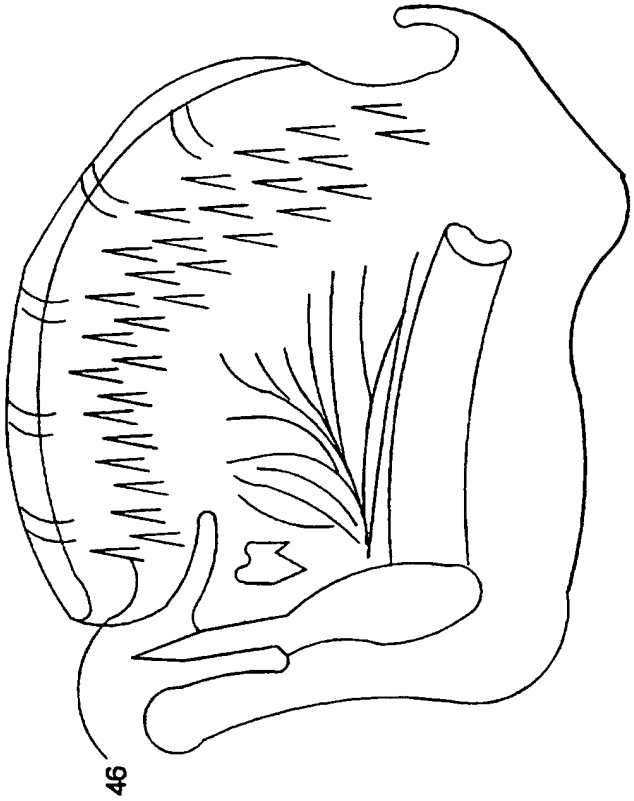

FIG.13

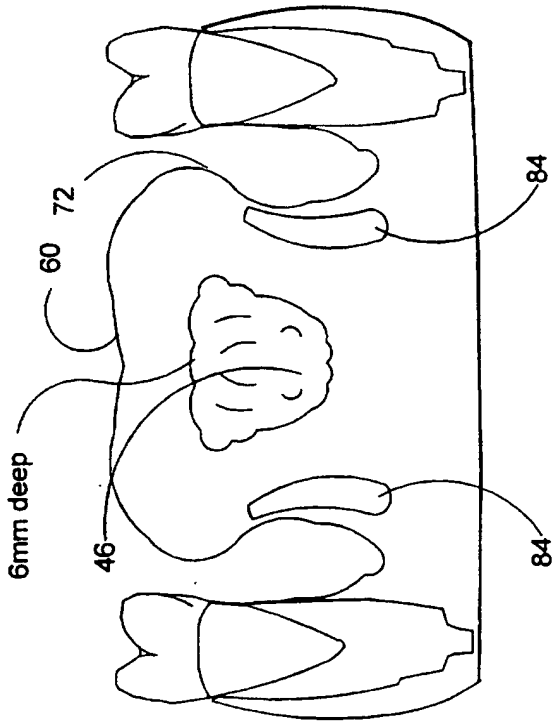

FIG.12

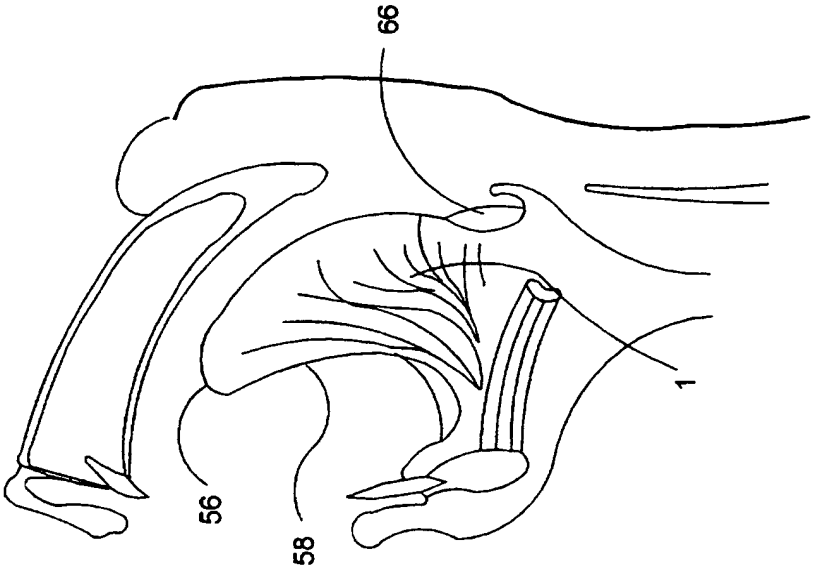

FIG.15

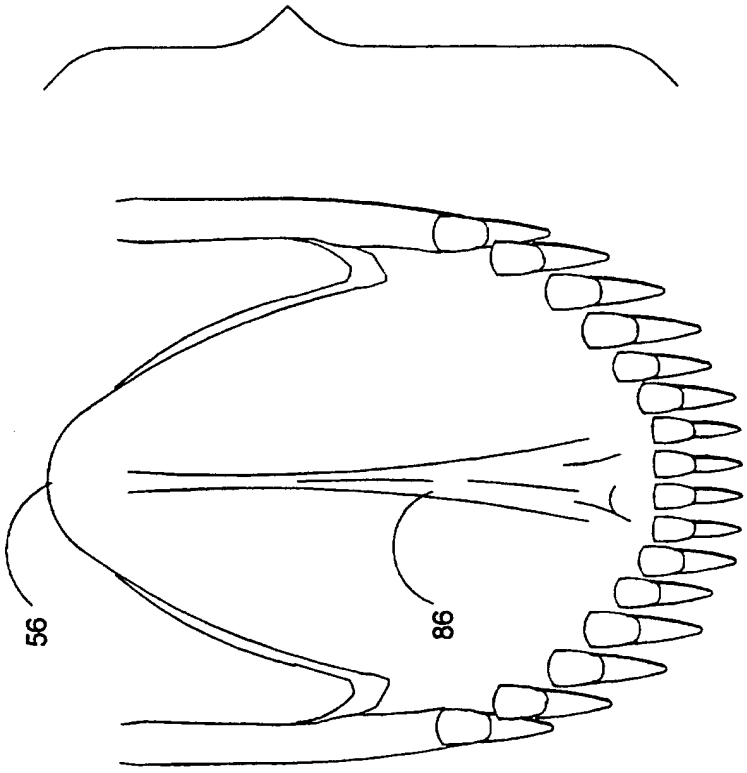

FIG.14

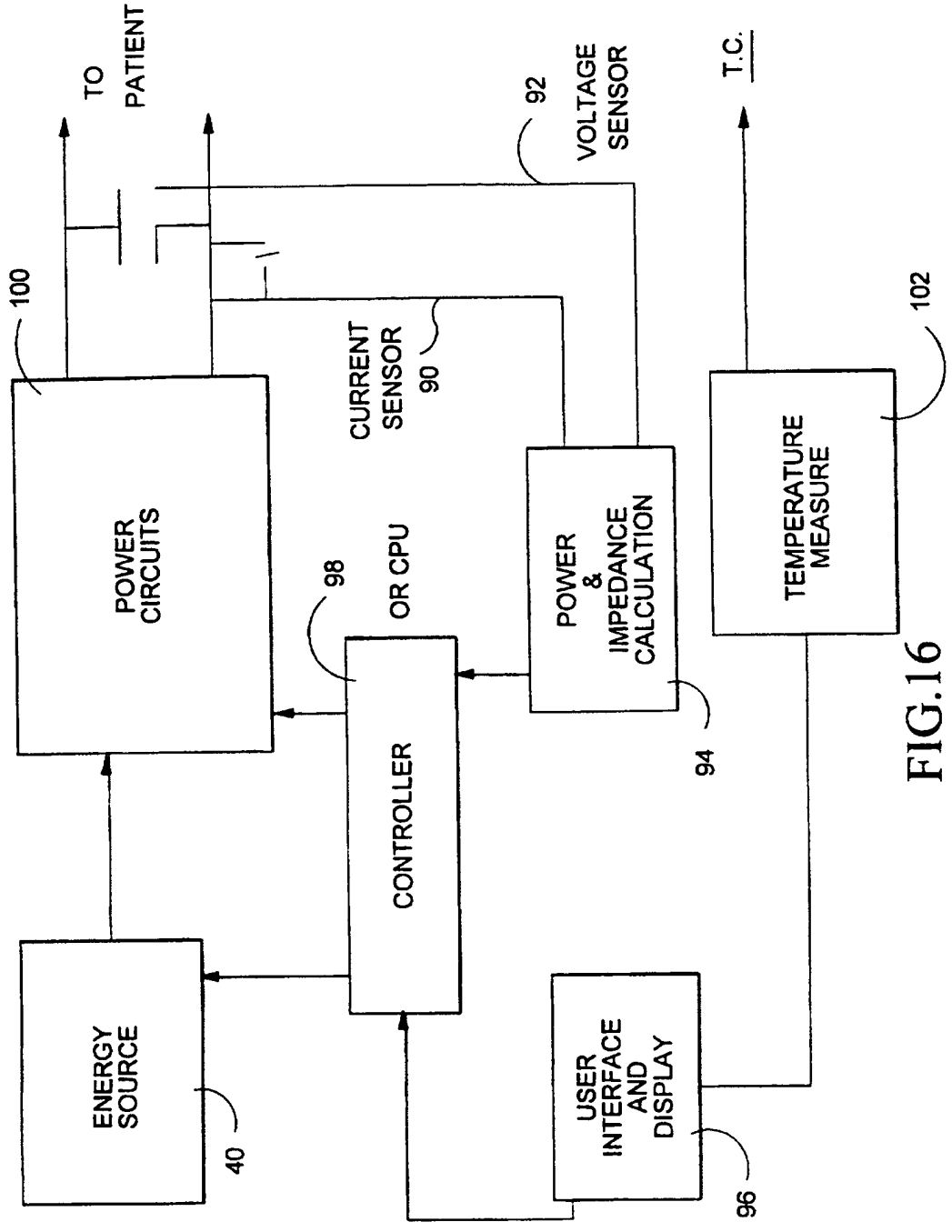
TO PATIENT
92
VOLTAGE SENSOR
T.C.
100
CURRENT SENSOR
90
102
POWER CIRCUITS
98
OR CPU
POWER & IMPEDANCE CALCULATION
TEMPERATURE MEASURE
CONTROLLER
94
ENERGY SOURCE
40
USER INTERFACE AND DISPLAY
96

FIG.16

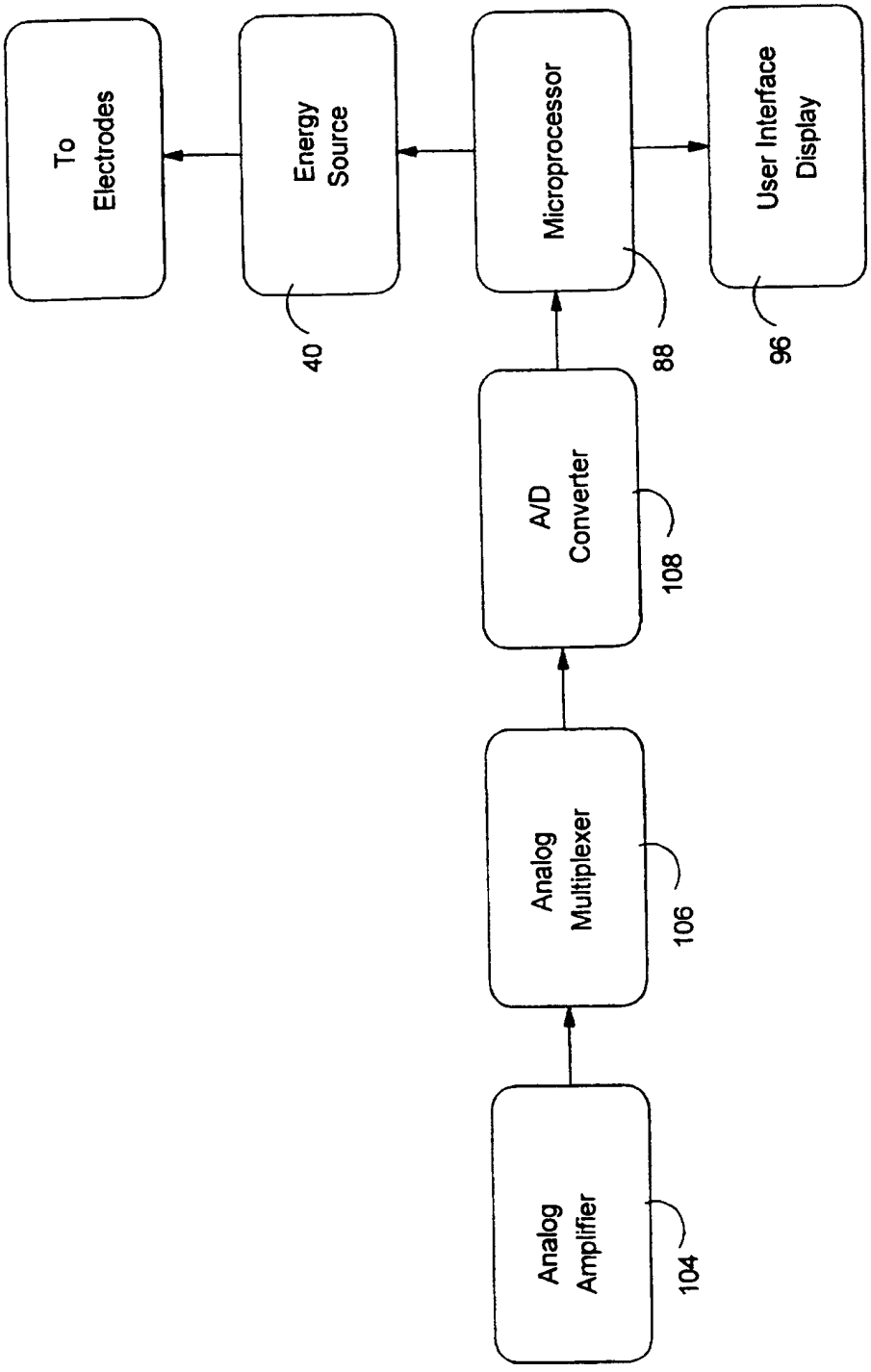
To Electrodes
Energy Source
Microprocessor
User Interface Display
40
88
96
A/D Converter
108
Analog Multiplexer
106
Analog Amplifier
104

FIG.17

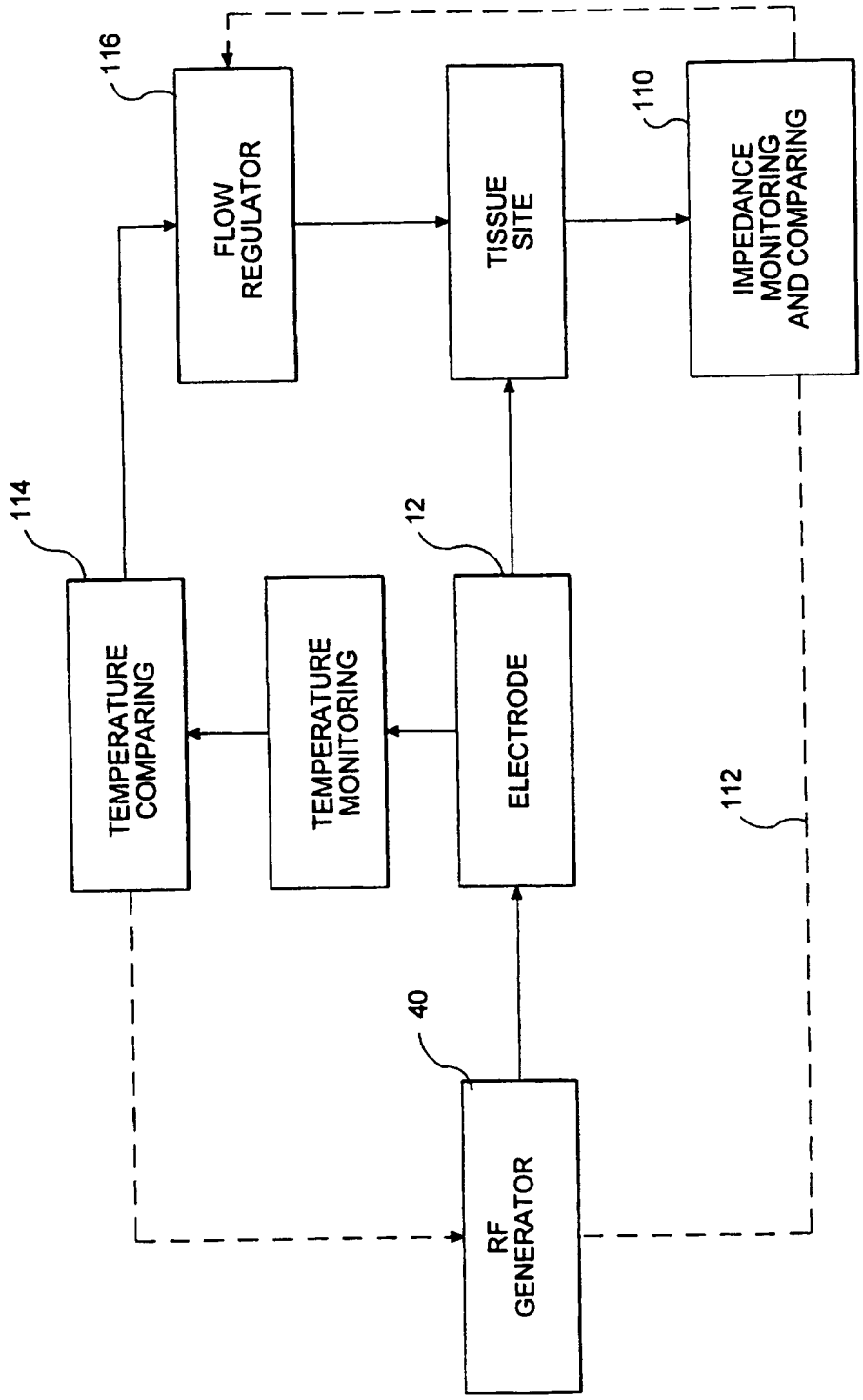
116
FLOW REGULATOR
TISSUE SITE
110
IMPEDANCE MONITORING AND COMPARING
114
12
TEMPERATURE COMPARING
TEMPERATURE MONITORING
ELECTRODE
112
40
RF GENERATOR

FIG. 18

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/US 97/02769

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61B17/39 A61N5/04 A61N1/40

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A61B A61N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 95 19142 A (VIDAMED) 20 July 1995 see abstract; figures 2,3	
A	WO 95 18575 A (VIDAMED) 13 July 1995 see abstract	
A	EP 0 608 609 A (CARDIAC PATHWAYS) 3 August 1994 see abstract; figure 1	
A	US 5 334 196 A (NARDELLA) 2 August 1994 see abstract; figures 1-4	
A	EP 0 139 607 A (YEDA RESEARCH) 2 May 1985 see figures 7,8A	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 June 1997	02.07.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Papone, F

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 97/02769

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: ALL
because they relate to subject matter not required to be searched by this Authority, namely:
All claims relate to surgical method, see Rule 39.1(iv) PCT.
Search conducted in light of description.

2. [ ] Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

.nformation on patent family members

Int ional Application No
PCT/US 97/02769

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9519142 A	20-07-95	US 5542915 A	06-08-96
		AU 1560295 A	01-08-95
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		JP 2562861 B	11-12-96
		JP 6254103 A	13-09-94
		US 5423811 A	13-06-95
		US 5545161 A	13-08-96
US 5334196 A	02-08-94	NONE	
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		AU 577318 B	22-09-88
		AU 3382284 A	18-04-85
		JP 4079671 B	16-12-92
		JP 60108062 A	13-06-85